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MULTICRITERIA ANALYSIS IN ESG-ORIENTED PORTFOLIO OPTIMIZATION

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Abstract. The article discusses multicriteria analysis as a methodological tool for integrating financial and non-financial ESG criteria in portfolio optimization tasks. *The relevance of the study* is determined by the fact that the classical portfolio selection model based on the return-risk ratio no longer fully reflects the current requirements of sustainable investment. As the importance of environmental, social and governance factors increases, investment decisions become multidimensional and require the use of methods that can combine diverse indicators into a single analytical system. *The purpose of the article* is to systematize scientific approaches to the use of multicriteria analysis in ESG-oriented portfolio optimization. *The research methodology* is based on a review and comparative analysis of scientific literature on portfolio theory, MCDA/MCDM methods, socially responsible investment and ESG integration. Special attention is given to the functions of multicriteria analysis, including the normalization of financial and ESG indicators, the determination of criterion weights, the ranking of assets, the formation of integrated assessments and the search for a balance between profitability, risk and sustainability. *The review results show* that multicriteria analysis expands the traditional portfolio optimization model and allows taking into account not only financial efficiency, but also long-term non-financial risks of companies. It has been established that MCA can be applied at various stages of the investment process:

preliminary ESG screening, ESG scoring, asset ranking and the inclusion of ESG criteria in optimization models. It is shown that TOPSIS, PROMETHEE, VIKOR, AHP, Entropy, CRITIC methods and their hybrid combinations provide a more transparent and explainable portfolio selection procedure. The article concludes that multicriteria analysis is not an alternative to classical portfolio theory, but its methodological extension in the context of sustainable finance. *The practical significance of the study* lies in the fact that its application makes it possible to form more balanced investment decisions that combine financial rationality, ESG priorities and investor preferences.

Keywords: multicriteria analysis; MCDA; MCDM; ESG; portfolio optimization; sustainable investing; socially responsible investing; financial criteria; non-financial criteria; investment portfolio

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ESG-БАҒДАРЛАНҒАН ПОРТФЕЛЬДІ ОҢТАЙЛАНДЫРУДАҒЫ КӨП КРИТЕРИАЛДЫ ТАЛДАУ

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Аннотация. Мақалада портфельді оңтайландыру міндеттерінде қаржылық және қаржылық емес ESG критерийлерін біріктірудің әдіснамалық құралы ретінде көп критериалды талдау қарастырылады. *Зерттеудің өзектілігі*

кірістілік пен тәуекел арақатынасына негізделген портфельді таңдаудың классикалық моделі тұрақты инвестициялаудың қазіргі талаптарын толық көрсете алмайтындығымен айқындалады. Экологиялық, әлеуметтік және басқарушылық факторлардың маңыздылығы артқан жағдайда инвестициялық шешімдер көпөлшемді сипатқа ие болады, бұл әртүрлі көрсеткіштерді біртұтас аналитикалық жүйеге біріктіре алатын әдістерді қолдануды қажет етеді. *Мақаланың мақсаты* — ESG-бағдарланған портфельді оңтайландыруда көп критериалды талдауды қолданудың ғылыми тәсілдерін жүйелеу. *Зерттеудің әдіснамалық негізін* портфель теориясы, MCDA/MCDM әдістері, әлеуметтік жауапты инвестициялау және ESG-интеграция бойынша ғылыми әдебиеттерге шолу және салыстырмалы талдау құрайды. Көп критериалды талдаудың қаржылық және ESG көрсеткіштерін нормалау, критерийлер салмағын анықтау, активтерді ранжирлеу, интегралды бағаларды қалыптастыру және кірістілік, тәуекел мен тұрақтылық арасындағы тепе-теңдікті іздеу сияқты функцияларына ерекше назар аударылады. *Шолу нәтижелері* көп критериалды талдау портфельді оңтайландырудың дәстүрлі моделін кеңейтетінін және қаржылық тиімділікпен қатар компаниялардың ұзақ мерзімді қаржылық емес тәуекелдерін де ескеруге мүмкіндік беретінін көрсетті. МКА инвестициялық процестің әртүрлі кезеңдерінде: алдын ала ESG-скринингте, ESG-скоринг құруда, активтерді ранжирлеуде және ESG критерийлерін оңтайландыру модельдеріне енгізуде қолданылуы мүмкін екені анықталды. TOPSIS, PROMETHEE, VIKOR, AHP, Entropy, CRITIC әдістері және олардың гибридті комбинациялары портфельді таңдаудың неғұрлым ашық және түсінікті рәсімін қамтамасыз ететіні көрсетілді. Көп критериалды талдау классикалық портфель теориясына балама емес, тұрақты қаржыландыру жағдайындағы оның әдіснамалық кеңеюі деген қорытынды жасалды. *Зерттеудің практикалық маңызы* оны қолдану қаржылық ұтымдылықты, ESG басымдықтарын және инвестордың қалауларын біріктіретін теңгерімді инвестициялық шешімдерді қалыптастыруға мүмкіндік беретіндігімен айқындалады.

Түйін сөздер: көп критериалды талдау; MCDA; MCDM; ESG; портфельді оңтайландыру; тұрақты инвестициялау; әлеуметтік жауапты инвестициялау; қаржылық критерийлер; қаржылық емес критерийлер; инвестициялық портфель

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МНОГОКРИТЕРИАЛЬНЫЙ АНАЛИЗ В ESG-ОРИЕНТИРОВАННОЙ ПОРТФЕЛЬНОЙ ОПТИМИЗАЦИИ

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Аннотация. В статье рассматривается многокритериальный анализ как методологический инструмент интеграции финансовых и нефинансовых критериев ESG в задачах портфельной оптимизации. *Актуальность исследования* обусловлена тем, что классическая модель портфельного выбора, основанная на соотношении доходности и риска, уже не в полной мере отражает современные требования устойчивого инвестирования. В условиях роста значимости экологических, социальных и управленческих факторов инвестиционные решения приобретают многомерный характер, что требует применения методов, способных объединять разнородные показатели в единую аналитическую систему. *Цель статьи* состоит в систематизации научных подходов к использованию многокритериального анализа в ESG-ориентированной портфельной оптимизации. *Методологическую основу исследования* составляют обзор и сравнительный анализ научной литературы по портфельной теории, MCDA/MCDM-методам, социально ответственному инвестированию и ESG-интеграции. Особое внимание уделено функциям многокритериального анализа: нормализации финансовых и ESG-показателей, определению весов критериев, ранжированию активов, формированию интегральных оценок и поиску компромисса между доходностью, риском и устойчивостью. *Результаты обзора показывают*, что многокритериальный анализ расширяет традиционную модель портфельной оптимизации и позволяет учитывать не только финансовую эффективность, но и долгосрочные нефинансовые риски компаний. Установлено, что МКА может применяться на различных этапах инвестиционного процесса: при предварительном ESG-скрининге, построении ESG-скоринга, ранжировании активов и включении ESG-критериев в оптимизационные модели. Показано, что методы TOPSIS, PROMETHEE, VIKOR, AHP, Entropy, CRITIC и их

гибридные комбинации обеспечивают более прозрачную и объяснимую процедуру портфельного выбора. Сделан вывод, что многокритериальный анализ является не альтернативой классической портфельной теории, а ее методологическим расширением в условиях устойчивого финансирования. *Практическая значимость исследования* заключается в том, что его применение позволяет формировать более сбалансированные инвестиционные решения, объединяющие финансовую рациональность, ESG-приоритеты и предпочтения инвестора.

Ключевые слова: многокритериальный анализ; MCDA; MCDM; ESG; портфельная оптимизация; устойчивое инвестирование; социально ответственное инвестирование; финансовые критерии; нефинансовые критерии; инвестиционный портфель

Introduction. Introduction. In recent decades, portfolio optimization has undergone a significant methodological transformation. If in classical financial theory the investment choice was mainly considered through the ratio of expected return and risk, then in modern conditions this approach is no longer sufficient to describe the real behavior of investors. The increasing complexity of financial markets, increasing uncertainty, increasing climate and social risks, as well as the development of the concept of sustainable financing have led to the need for a broader understanding of investment efficiency. As a result, the portfolio is increasingly viewed not only as a tool for generating returns, but also as a mechanism for managing long-term financial and non-financial risks.

The traditional model of portfolio choice based on the mean–variance approach has laid the foundation for modern investment theory. It allowed us to formalize risk, show the importance of diversification, and justify building an effective portfolio boundary (Markowitz, 1952). However, this model relies primarily on two key criteria — profitability and risk. In the context of modern investment practice, such two-criteria logic turns out to be limited, since investors are forced to take into account a broader set of factors: asset liquidity, financial stability of issuers, quality of corporate governance, industry structure, reputational risks, environmental responsibility and social impact of companies (Zopounidis, Doumpos, 2002; Aouni et al., 2018).

Of particular importance in this context is the integration of ESG criteria reflecting the environmental, social and managerial aspects of companies' activities. The ESG approach is gradually becoming one of the key areas for the development of responsible and sustainable investment. He suggests that a company's investment attractiveness should be assessed not only by financial results, but also by its ability to reduce environmental risks, ensure social responsibility, maintain transparent corporate governance, and adapt to long-term sustainable development challenges (Xidonas et al., 2024; Bertelli and Torricelli, 2023). The inclusion of ESG factors in portfolio optimization changes the very formulation of the investment objective:

the portfolio must be effective not only in terms of profitability and risk, but also from a position of sustainability.

However, the practical integration of ESG criteria into portfolio models is associated with a number of methodological difficulties. First, financial and non-financial indicators have different natures, different units of measurement, and different ways of interpretation. Profitability, volatility, liquidity, or capitalization are expressed quantitatively, whereas ESG estimates are often presented in the form of ratings, indexes, expert scores, or aggregated indicators. Secondly, ESG data is characterized by heterogeneity and insufficient comparability: different providers may evaluate the same companies differently due to differences in methodologies, criteria and weights (Berg, Kolbel, Rigobon, 2022). Thirdly, there may be contradictions between financial and ESG goals, since maximizing profitability does not always coincide with maximizing sustainability.

It is in these conditions that the importance of multi-criteria analysis as a methodological tool for portfolio optimization increases. Multi-criteria decision analysis allows making decisions in the presence of several criteria, some of which may be quantitative, some qualitative, and the criteria themselves may be in conflict with each other (Zopounidis, Doumpos, 2002; Spronk, Steuer, Zopounidis, 2005). Its use in financial tasks is due to the fact that an investment decision is rarely reduced to a single indicator. In practice, an investor evaluates alternatives simultaneously by profitability, risk, liquidity, issuer stability, ESG profile, and personal preferences (Aouni et al., 2018).

In the tasks of ESG-oriented portfolio optimization, multi-criteria analysis performs an integration function. It allows you to combine financial and non-financial criteria into a single analytical system, normalize heterogeneous indicators, determine the weights of criteria, rank assets and form the basis for further portfolio optimization. At the same time, ICA can be used as an independent asset selection tool, or as part of a hybrid model combining multi-criteria analysis and multi-purpose optimization (Wu et al., 2022; García et al., 2019). This approach is especially important for sustainable investment, as it allows not only to exclude companies with low ESG indicators, but also to flexibly assess their investment attractiveness, taking into account a combination of financial and non-financial characteristics.

The relevance of this review article is determined by several circumstances. First, the development of ESG investing requires more accurate and transparent methods for integrating non-financial criteria into investment models. The simple use of the ESG rating as an additional indicator does not always allow us to reveal the internal structure of the company's sustainability and can lead to simplified conclusions. Secondly, the growing heterogeneity of ESG data reinforces the need for methods that can work with heterogeneous, partially subjective and disparate indicators (Berg, Kolbel, Rigobon, 2022). Third, traditional portfolio optimization models need methodological expansion to take into account not only financial efficiency, but also the long-term sustainability of an investment decision.

The scientific significance of the topic lies in the fact that multi-criteria analysis allows us to rethink the very logic of portfolio optimization. In the classical approach, a portfolio is considered effective if it provides an optimal ratio of risk and return. In the multi-criteria ESG-oriented model, efficiency becomes a more complex category. It includes financial performance, sustainability, quality of corporate governance, social responsibility, and compliance with investor preferences. Consequently, the ICA facilitates the transition from a narrow model of financial efficiency to a more comprehensive model of investment sustainability.

Despite the active development of research in this field, the existing literature remains fragmented. Some studies focus on the theoretical aspects of multicriteria analysis in finance (Zopounidis, Doumpos, 2002; Spronk, Steuer, Zopounidis, 2005), others on multi—purpose portfolio selection models (Xidonas, Mavrotas, Psarras, 2010; Xidonas et al., 2024), and others on ESG-oriented investment strategies and constraints (Bertelli and Torricelli, 2023), the fourth — on the problems of ESG data quality and rating discrepancies (Berg, Kolbel, Rigobon, 2022). However, a systematization of approaches is required to show how the ICA can act as a connecting methodological tool between financial criteria, ESG indicators and portfolio optimization objectives.

The purpose of the article is to systematize scientific approaches to the application of multi-criteria analysis as a methodological tool for integrating financial and non-financial ESG criteria in portfolio optimization tasks.

To achieve this goal, the article solves the following tasks: to reveal the limitations of the classical two-criterion model of portfolio selection; to summarize the main areas of application of ICA in financial analysis and portfolio optimization; to determine the role of ESG criteria in the modern investment model; to identify the methodological capabilities of ICA for combining financial and non-financial indicators; to systematize the main scenarios of ESG integration into portfolio selection to determine the advantages, limitations and prospects of using ICA in ESG-oriented portfolio optimization.

The object of the research is methodological approaches to portfolio optimization in the context of sustainable investment. The subject of the research is multi-criteria analysis as a tool for integrating financial and ESG criteria into the portfolio selection system.

The methodological basis of the article is a review and comparative analysis of scientific literature on portfolio theory, multi-criteria analysis, socially responsible investing and ESG portfolio optimization. Special attention is paid to papers that consider MCDA/MCDM methods, multipurpose optimization, ESG-scoring, ESG-screening, ESG-optimization, as well as the problem of ESG ratings discrepancy. This approach allows not only to summarize existing research, but also to identify the methodological potential of ICA for the further development of sustainable portfolio management.

The structure of the article is as follows. The Literature Review section analyzes

the main areas of scientific discussion on portfolio optimization, ICA, and ESG investing. The section "Materials and methods" reveals the logic of the review study and the systematization of sources. The "Results" section highlights the key functions of the ICA in the tasks of integrating financial and non-financial criteria. The Discussion section discusses the theoretical and practical implications of the use of ICA, its advantages and limitations. In conclusion, the main conclusions and prospects for further research are formulated.

Materials and methods. The present study is carried out in the format of a review article aimed at systematizing scientific approaches to the application of multicriteria analysis in ESG-oriented portfolio optimization. The theoretical and methodological nature of the work determined the choice of research material: scientific publications on portfolio theory, multicriteria analysis, socially responsible investing, ESG integration and multi-purpose optimization of the investment portfolio were used as the main source of analysis.

The methodological logic of the research is based on the understanding of portfolio optimization as a multi-criteria decision-making procedure. In the classical model, investment choice is considered primarily through the ratio of risk and return (Markowitz, 1952). However, the development of sustainable financing and ESG investment expands this task statement, since the investor must take into account not only financial efficiency, but also non-financial characteristics of companies: environmental responsibility, social impact, quality of corporate governance and long-term sustainability of the business model.

The study analyzed several interrelated areas of scientific literature. The first group of sources includes works on classical portfolio theory and the mean–variance approach, which formulate the basic logic of risk assessment, profitability and diversification (Markowitz, 1952). The second group is represented by studies on multicriteria analysis in financial decision-making, revealing the possibilities of MCDA/MCDM for comparing investment alternatives in the presence of several conflicting criteria (Zopounidis, Doumpos, 2002; Aouni et al., 2018; Spronk, Steuer, Zopounidis, 2005). The third group covers work on multi-purpose portfolio optimization, where portfolio selection is considered as a task beyond the classical two-criteria model (Xidonas, Mavrotas, Psarras, 2010; Xidonas et al., 2024). The fourth group includes research on ESG investing, socially responsible portfolio choice, sustainable investment strategies, and ESG data quality issues (García et al., 2019; Berg, Kölbel, Rigobon, 2022; Bertelli, Torricelli, 2023; Taheripour et al., 2025).

The selection of literature was based on the principle of thematic relevance. The analysis included publications that met one or more criteria: revealed the theoretical foundations of portfolio optimization; considered methods of multi-criteria analysis in financial problems; proposed models for integrating ESG or CSR criteria into investment choices; analyzed the problems of ESG ratings and non-financial data; applied multi-purpose optimization methods or hybrid models to portfolio selection

problems. This approach made it possible to form a corpus of sources sufficient for theoretical generalization and identification of methodological functions of ICA in ESG-oriented portfolio optimization.

The study did not involve conducting its own empirical calculation based on market data, since its purpose is not to test a specific investment portfolio, but to systematize existing scientific approaches. Therefore, the main emphasis was placed on qualitative comparative analysis, conceptual classification and analytical generalization of the results of previously published studies. This format corresponds to the objectives of the review article, where the main result is to identify the structure of the scientific field, the main approaches, limitations and prospects for further research.

The research methodology included several successive stages. At the first stage, the theoretical framework of the analysis was defined. The classical portfolio selection model based on the risk-return ratio (Markowitz, 1952) was used as a starting point. This model was considered as the basic methodological basis against which modern extensions of portfolio optimization were analyzed.

At the second stage, the systematization of research on multicriteria analysis in finance was carried out. Special attention was paid to the functions that MCDA/MCDM methods perform in financial decision-making: ranking alternatives, determining weights of criteria, aggregating heterogeneous indicators, finding a compromise between conflicting goals and increasing transparency of investment choice (Zopounidis, Doumpos, 2002; Aouni et al., 2018; Spronk, Steuer, Zopounidis, 2005).

At the third stage, publications on ESG integration and socially responsible investing were analyzed. ESG criteria were considered as non-financial indicators capable of influencing the long-term sustainability of the company and the level of portfolio risk. Particular attention was paid to the problem of heterogeneity of ESG data and divergence of ESG ratings, since this problem determines the need for more transparent methods of aggregation and interpretation of non-financial indicators (Berg, Kolbel, Rigobon, 2022).

At the fourth stage, financial and ESG criteria were compared in the logic of a multi-criteria analysis. The financial criteria included profitability, risk, liquidity, capitalization, volatility, Sharpe ratio, beta and other indicators of market efficiency. Non-financial criteria included environmental, social, and management parameters, including the ESG rating, components E, S, and G, the quality of information disclosure, the level of corporate responsibility, and the sustainability of the business model. This separation allowed us to show that portfolio optimization in the ESG context requires combining indicators of different nature.

At the fifth stage, the main scenarios for using ICA in ESG-oriented portfolio optimization were identified: ESG-screening, ESG-scoring and ESG-optimization. In the first case, the ICA is used to pre-filter assets, in the second - to build an integral assessment or rating, in the third - to include ESG criteria in the target

function, constraints or multi-purpose model of portfolio selection (Xidonas et al., 2024; Bertelli, Torricelli, 2023). This classification made it possible to structure various forms of ESG integration and show that ICA can be applied at different stages of the investment process.

A comparative methodological approach was used as the main analytical tool. It allowed us to compare classical portfolio theory, multi-criteria methods and ESG-oriented models in several parameters: the objective function, the type of criteria, the nature of the data, the role of investor preferences, the degree of transparency and applicability to sustainable investment. The results of this comparison formed the basis for the subsequent systematization of the functions of the ICA.

The study also applied a classification procedure aimed at grouping ICA methods according to their functional purpose. The TOPSIS, VIKOR, and PROMETHEE methods were considered as tools for ranking alternatives and finding compromise solutions; AHP and BWM - as methods for expert determination of weights; Entropy and CRITIC - as methods of objective weighing based on the data structure; hybrid approaches - as combinations of several procedures to increase the stability of results (Goutte et al., 2025; Ahmadi, Peivandizadeh, 2022).

Particular attention was paid to data normalization, since financial and ESG indicators are expressed on different scales and cannot be directly compared. In the multi-criteria model, normalization is an obligatory stage of ESG integration, ensuring the correct aggregation of profitability, risk, liquidity, ESG rating and other criteria. It was taken into account that some of the criteria have a maximization direction, such as profitability or ESG rating, and some have a minimization direction, such as risk, volatility or carbon intensity.

The generalized procedure for applying ICA in ESG-oriented portfolio optimization includes the following steps: defining the investment universe; selecting financial and ESG criteria; normalizing data; determining the weights of criteria; aggregating indicators; ranking assets; selecting or optimizing a portfolio; analyzing the sensitivity of results. This procedure shows that a multi-criteria analysis can be integrated into the portfolio process sequentially, from selecting criteria to verifying the sustainability of the final decision.

Thus, the research methodology is based on a systematic review, comparative analysis and analytical classification of existing scientific approaches. Unlike empirical studies aimed at calculating specific portfolios, this article focuses on identifying the methodological potential of ICA. This allows us to determine how multi-criteria analysis can be used to integrate financial and ESG criteria, what functions it performs in portfolio optimization, what advantages it provides, and what limitations require further research.

Literary review. The scientific discussion on portfolio optimization traditionally begins with the classical Markowitz model, in which the investment choice is considered through the ratio of expected return and risk. This model became the foundation of modern portfolio theory, as it was the first to propose a

formalized approach to asset diversification and showed that portfolio performance is determined not only by the characteristics of individual securities, but also by the relationships between them (Markowitz, 1952). As part of the mean–variance approach, an investor strives to form a portfolio that provides the maximum expected return at a given level of risk or minimal risk at a given return. However, the limitations of this model are manifested in the fact that it reduces the investment decision mainly to two financial criteria and does not take into account a wider range of factors affecting the sustainability and long-term investment attractiveness of assets.

As financial markets become more complex and investment priorities transform, the scientific literature has increased its focus on multi-criteria decision-making methods. Zopounidis and Doumpos note that most financial tasks are multi-criteria in nature, since an investor, bank, fund, or management company rarely makes decisions based on a single indicator (Zopounidis and Doumpos, 2002). In addition to profitability and risk, financial analysis takes into account liquidity, solvency, financial stability, quality of management, market capitalization, debt burden and other parameters. Consequently, the multi-criteria decision aid methods allow not only to compare alternatives according to several criteria, but also to make the financial selection process more structured and transparent.

This approach was further developed in the research of Aouni et al., which emphasizes the increasing importance of multicriteria methods specifically for portfolio selection tasks (Aouni et al., 2018). Portfolio optimization in such works is considered not only as a mathematical procedure for distributing weights between assets, but also as a management decision reflecting the goals, limitations and preferences of the investor. This is especially important in situations where the selection criteria are conflicting: high returns may be accompanied by high risk, high liquidity by low returns, and high sustainability by limited diversification. In this setting, multi-criteria analysis becomes a tool for finding a compromise between the various goals of investment choice.

An important contribution to the development of a multi-criteria approach to portfolio design was made by Xidonas, Mavrotas and Psarras, who consider portfolio selection as a multi-objective mathematical programming task (Xidonas, Mavrotas, Psarras, 2010). Their approach shows that an effective portfolio can be assessed not only by criteria of profitability and risk, but also by additional dimensions reflecting investor preferences and the specifics of the investment environment. This expands the traditional understanding of portfolio performance and creates a methodological basis for the inclusion of non-financial criteria in investment models.

The multi-criteria approach has become particularly relevant in connection with the development of ESG investment. The ESG approach assumes that investment decisions should take into account the environmental, social and managerial characteristics of companies. Environmental criteria reflect the business's impact

on the environment, climate risks, resource use, and decarbonization policies. Social criteria are related to labor practices, relationships with employees, consumers, and society. Management criteria characterize the quality of corporate governance, transparency, ownership structure, protection of shareholders' rights, and anti-corruption mechanisms (Xidonas et al., 2024; Berg, Kolbel, Rigobon, 2022; Bertelli, Torricelli, 2023). The inclusion of these factors changes the nature of the portfolio choice, as the investment attractiveness of an asset begins to be determined not only by its financial profitability, but also by the level of stability of the company.

Research on ESG portfolio optimization shows that ESG factors can be used in an investment model in different ways. In their simplest form, they act as a screening tool when companies that do not meet the minimum sustainability requirements are excluded from the investment universe. A more complex approach involves building an ESG rating or ESG scoring, which is used to rank assets. The most advanced form of integration involves the inclusion of ESG indicators directly into the optimization model as a separate objective function, constraint, or additional selection criterion (Xidonas et al., 2024; Bertelli and Torricelli, 2023). Thus, ESG integration is gradually moving from an external filter to a full-fledged element of portfolio optimization.

Xidonas et al. ESG portfolio design is considered as a multi-purpose task in which sustainability becomes an independent measurement of portfolio efficiency along with profitability and risk (Xidonas et al., 2024). This means that the investor strives not only for financial optimality, but also for the formation of a portfolio that meets certain environmental, social and managerial requirements. This approach is fundamentally different from the classical two-criteria model, as portfolio performance becomes multidimensional.

Bertelli and Torricelli also emphasize that the introduction of ESG restrictions affects the structure of the optimal portfolio (Bertelli and Torricelli, 2023). ESG criteria can change not only the composition of assets, but also their weights, industry structure, level of diversification, and risk-return ratio. This shows that ESG integration is not a neutral complement to the classic portfolio model. On the contrary, it can significantly change the result of optimization and therefore requires special methodological tools that simultaneously take into account financial and non-financial parameters.

One of the most serious problems of ESG investing is the quality and comparability of ESG data. Berg, Kölbel, and Rigobon show that the ESG ratings of different providers can differ significantly from each other (Berg, Kölbel, and Rigobon, 2022). The reasons for these discrepancies are related to differences in methodologies, sets of indicators, weights of individual criteria, and data aggregation methods. As a result, the same company may receive a high rating from one provider and a lower rating from another. For portfolio optimization, this creates methodological uncertainty, since the final portfolio may depend on the selected source of ESG data.

In this context, multi-criteria analysis has an important advantage. It allows us not to limit ourselves to using a single aggregated ESG score, but to consider the ESG as a system of separate criteria. Environmental, social, and management indicators can be analyzed separately, normalized, weighted, and then aggregated depending on the investor's goals. This approach makes ESG integration more transparent and reduces the risk of mechanical use of ready-made ratings. In addition, the ICA allows for sensitivity analysis and verification of how much the final asset rating depends on changes in weights or composition of criteria (Berg, Kölbel, Rigobon, 2022; Goutte et al., 2025; Taheripour et al., 2025).

In the literature, there are several groups of ICA methods used in the tasks of financial choice and portfolio optimization. The most common ones include TOPSIS, PROMETHEE, VIKOR, AHP, Entropy, CRITIC, as well as their hybrid combinations (Spronk, Steuer, Zopounidis, 2005; Goutte et al., 2025; Ahmadi, Peivandizadeh, 2022). The TOPSIS method is used to assess the proximity of alternatives to the ideal solution. In a portfolio task, this allows you to identify assets that simultaneously have high returns, low risk, acceptable liquidity and high ESG indicators. PROMETHEE is based on a pairwise comparison of alternatives and allows you to identify preference relationships between assets. VIKOR is focused on finding a compromise solution in the presence of conflicting criteria. AHP is used for expert determination of criteria weights, whereas Entropy and CRITIC allow calculating weights based on the information structure of the data.

Hybrid models occupy a special place in modern literature because they allow combining the advantages of different methods. One method can be used to determine the weights of criteria, another to rank assets, and the third to verify the sustainability of results. Goutte et al. It is shown that the use of several MCDA strategies in portfolio optimization makes it possible to compare alternative solutions and assess their sustainability in terms of market dynamics (Goutte et al., 2025). This is especially important for ESG portfolios, as the results may be sensitive to the choice of normalization method, the method of calculating weights, and the initial ESG data.

In research on socially responsible investing, ICA is often combined with multi-purpose optimization. Wu et al. propose an integrated model combining multi-criteria decision-making and multi-objective optimization for socially responsible portfolio selection tasks (Wu et al., 2022). This approach has important methodological significance.: ICA is used to evaluate and rank assets based on a set of financial and non-financial criteria, while multi-purpose optimization is used to determine the structure of a portfolio. As a result, a model is formed that combines the explainability of a multi-criteria analysis and the mathematical rigor of an optimization approach.

García et al. They develop this direction through the use of a fuzzy multi-criteria approach to the selection of socially responsible portfolios (García et al., 2019). Fuzzy models are especially useful in conditions of uncertainty, when data is not

always accurate, and investor preferences can be expressed not in strict numerical values, but in qualitative estimates. This is especially important for ESG investing, since non-financial indicators are often of an expert nature, and their interpretation depends on the assessment methodology.

Interactive approaches to socially responsible portfolio selection also reflect an important trend in the development of literature. Hanine et al. It is emphasized that the investor should be considered not as a passive recipient of the optimal solution, but as an active participant in the selection process (Hanine et al., 2021). In such models, the investor's preferences can be clarified, reviewed, and included in the decision-making process. This is of particular importance for ESG portfolios, as different investors may evaluate the importance of environmental, social, and management criteria in different ways.

Modern literature also shows that ESG criteria are gradually beginning to be considered not only as value or reputational parameters, but also as elements of risk management. Taheripour et al. propose an ESG-based portfolio optimization model that includes historical indicators, forward estimates, and a credibilistic CVaR (Taheripour et al., 2025). This approach indicates the transition from static ESG scoring to a more complex assessment system that takes into account uncertainty and extreme risks. This is especially important because environmental, social and managerial risks may manifest themselves in the future through regulatory sanctions, reputational losses, rising costs, reduced investment attractiveness or deterioration of the company's financial results.

An analysis of the literature allows us to identify several methodological directions for integrating ESG criteria into portfolio optimization. The first area is related to ESG-screening, that is, the exclusion of companies that do not meet the minimum sustainability requirements. The second area is related to ESG-scoring, in which ESG indicators are aggregated into an integrated assessment of the company. The third direction is related to ESG-tilting, when asset weights change depending on their ESG profile. The fourth area is related to ESG optimization, where ESG criteria are directly integrated into the optimization model (Xidonas et al., 2024; Bertelli and Torricelli, 2023). ICA can be used in all these areas, but its role is especially increasing in ESG-scoring and ESG-optimization scenarios, where aggregation of heterogeneous criteria and search for a compromise between financial and non-financial goals are required.

Despite significant progress in the development of ESG-oriented portfolio selection models, the literature points to a number of unresolved issues. Firstly, the methodological heterogeneity of ESG data remains. Different rating agencies and providers use different approaches to assessing sustainability, which reduces the comparability of results (Berg, Kolbel, Rigobon, 2022). Secondly, the question of choosing a balance between financial and ESG criteria remains open. Too high an ESG weight can lead to a decrease in the financial efficiency of the portfolio, while too low a weight makes ESG integration a formality. Thirdly, many models remain

sensitive to the choice of normalization method and ranking algorithm. Fourth, there is not always sufficient verification of the sustainability of the results (Goutte et al., 2025; Taheripour et al., 2025).

It is these limitations that create a scientific gap, which justifies the need for further study of the ICA as a methodological tool for ESG integration. In existing studies, individual ICA methods, ESG portfolio optimization models, and sustainable investment issues are considered in sufficient detail. However, a more systematic generalization of how the ICA can perform an integration function between financial and non-financial criteria is required. Of particular importance is the analysis of at what stage of the portfolio processes the ICA is used most effectively: when selecting assets, determining weights, building an ESG rating, forming constraints or directly optimizing the portfolio.

Thus, the literature review shows that multicriteria analysis is one of the most promising methodological approaches to ESG-oriented portfolio optimization. Its advantage lies in the ability to combine profitability, risk, liquidity, financial stability and ESG indicators into a single decision-making system. Unlike the classical Markowitz model, the ICA allows for the multidimensional nature of modern investment choices. Unlike simple ESG screening, it provides a more flexible and transparent integration of non-financial criteria. Unlike fully automated optimization, it allows you to explicitly take into account the investor's preferences and explain the final decision.

In summary, the existing literature confirms that the development of portfolio optimization is moving from a two-criteria model "return - risk" to a multi-criteria model "return - risk - ESG - investor preferences". In this model, the ICA plays a key role, as it ensures the normalization of heterogeneous data, the determination of weights of criteria, the ranking of assets, the search for a compromise between conflicting goals and increasing the transparency of the investment decision. Consequently, the ICA can be considered not as a replacement for the classical portfolio theory, but as its methodological extension that meets modern requirements for sustainable financing and responsible investment.

Results. The review of the scientific literature shows that multicriteria analysis (MCA) is gradually becoming an important methodological tool in portfolio selection, especially in the context of the transition from traditional financial investment models to sustainable and responsible investing. While classical portfolio theory is based mainly on the relationship between expected return and risk (Markowitz, 1952), modern investment decisions are increasingly made under conditions of multiple objectives, heterogeneous data and the need to consider non-financial factors. These factors include environmental, social and governance characteristics of companies, corporate governance quality, information disclosure, climate risks, social responsibility and the long-term sustainability of business models (Zopounidis and Doumpos, 2002; Aouni et al., 2018; Berg, Kölbel and Rigobon, 2022).

The main result of the review is that MCA expands the traditional two-criteria portfolio choice model "return–risk" into a multidimensional investment decision-making system. In the classical model, assets are evaluated primarily through expected return, variance or standard deviation of returns, and the covariance structure of the portfolio. However, this approach does not fully reflect the non-financial characteristics of companies, which are becoming increasingly important in sustainable finance. An asset with high return and moderate risk may be less attractive if the company has weak corporate governance, a high environmental footprint or significant social risks (García et al., 2019; Xidonas et al., 2024; Bertelli and Torricelli, 2023).

MCA makes it possible to include such parameters in the portfolio selection process without abandoning the basic logic of optimization. As a result, a portfolio is considered not only as a set of financial instruments, but also as a set of companies with a specific sustainability profile. This changes the content of the investment task: the investor seeks not only to maximize return and minimize risk, but also to ensure that the portfolio complies with ESG priorities. This transformation is particularly important for institutional investors, whose decisions are increasingly assessed not only by financial performance, but also by compliance with the principles of responsible investment.

Another important result is that MCA allows quantitative and qualitative indicators of different nature to be combined. Financial criteria usually have a quantitative basis, including return, volatility, Sharpe ratio, beta, liquidity, capitalization, debt burden and market value. ESG criteria, by contrast, are often represented by ratings, expert assessments, disclosure indices or aggregated scores generated by specialized data providers (Berg, Kölbel and Rigobon, 2022). This heterogeneity makes MCA especially relevant, since it enables the normalization of diverse indicators, determination of criteria weights and formation of an integrated assessment of investment alternatives (Zopounidis and Doumpos, 2002; Spronk, Steuer and Zopounidis, 2005).

The review also shows that MCA helps formalize a compromise between different investment goals. In traditional portfolio theory, the main compromise is between risk and return. In ESG-oriented models, the number of conflicting objectives increases: investors may simultaneously seek higher returns, lower volatility, better ESG quality, a lower carbon footprint, exclusion of companies with weak governance and sufficient diversification (Wu et al., 2022; García et al., 2019; Xidonas et al., 2024). Through weighting, normalization and ranking, MCA makes these contradictions visible and manageable.

MCA can be applied at different stages of portfolio optimization. At the preliminary selection stage, it may be used to exclude companies that do not meet minimum financial or ESG requirements. At the evaluation stage, it can be used to build an integrated asset rating based on financial and non-financial characteristics. At the portfolio formation stage, MCA results may serve as input parameters for

further optimization, where the weights of assets are determined (Wu et al., 2022; García et al., 2019). Therefore, MCA does not necessarily replace mathematical optimization; rather, it can perform preparatory, filtering and integrative functions.

The most common groups of MCA methods used in financial decision-making and portfolio optimization include ranking methods, pairwise comparison methods, compromise solution methods, weighting methods and hybrid models (Aouni et al., 2018; Spronk, Steuer and Zopounidis, 2005; Goutte et al., 2025; Ahmadi and Peivandizadeh, 2022). TOPSIS is used to evaluate alternatives according to their closeness to the ideal solution. PROMETHEE allows preference relations between alternatives to be established. VIKOR is aimed at finding a compromise solution under conflicting criteria. AHP and BWM are mainly used to determine criteria weights, while Entropy and CRITIC allow weights to be calculated on the basis of data structure.

The choice of a specific MCA method depends on the nature of the investment task. If the purpose is to rank assets, TOPSIS, VIKOR, PROMETHEE or MULTIMOORA may be appropriate. If the task is to determine the relative importance of criteria, AHP, BWM, Entropy or CRITIC can be used. If the task involves uncertainty or subjectivity of ESG assessments, fuzzy, interval or stochastic modifications of MCA may be applied (García et al., 2019; Hanine et al., 2021).

ESG integration through MCA can be implemented through several methodological scenarios. The first is ESG screening, which involves the preliminary exclusion of companies that do not meet minimum sustainability requirements. The second is ESG scoring, where environmental, social and governance indicators are aggregated into an integrated rating. The third is ESG optimization, where ESG criteria are included directly in the portfolio optimization model as an objective function, constraint or additional criterion (Xidonas et al., 2024; Bertelli and Torricelli, 2023). These scenarios differ in the depth of ESG integration: screening is the simplest form, scoring requires aggregation of indicators, while optimization makes sustainability part of the portfolio selection model itself.

An important result of the review is that MCA increases the transparency and explainability of portfolio decisions. Classical optimization models are often sensitive to input data, and small changes in expected returns, covariance matrices or risk levels can lead to significant changes in asset weights. MCA makes the decision-making process more structured by showing which criteria were used, how they were normalized, what weights were assigned and why certain assets received higher or lower scores (Zopounidis and Doumpos, 2002; Berg, Kölbel and Rigobon, 2022; Spronk, Steuer and Zopounidis, 2005).

MCA also makes it possible to reflect individual investor preferences. In ESG investing, preferences are more complex than simple risk tolerance. One investor may prioritize environmental criteria, another may focus on social responsibility, while another may emphasize corporate governance or the balance between return and sustainability (Xidonas, Mavrotas and Psarras, 2010; García et al., 2019; Hanine et al., 2021). Through a system of weights, MCA allows the construction of

a portfolio that corresponds to a specific preference profile rather than a universal model.

The review further shows that MCA helps address the problem of ESG data quality. ESG ratings may differ significantly between providers because of differences in methodologies, indicators, weights and data sources (Berg, Kölbel and Rigobon, 2022). MCA does not completely eliminate this problem, but it makes the use of such data more transparent. The overall ESG rating can be decomposed into environmental, social and governance components; several data sources can be aggregated; and sensitivity analysis can be used to test the stability of results.

Finally, MCA provides a framework for comparing different portfolio strategies, including traditional portfolios, ESG-screened portfolios, ESG-tilted portfolios and ESG-optimized portfolios. Such comparison makes it possible to assess how ESG integration affects return, risk, diversification, sectoral structure and portfolio sustainability (Xidonas et al., 2024; Bertelli and Torricelli, 2023). For example, strict ESG screening may reduce diversification, while ESG tilting changes asset weights without fully excluding companies. ESG optimization, in turn, allows a compromise to be found between financial constraints and sustainability goals.

Thus, the results of the review confirm that multicriteria analysis is not an auxiliary tool, but an important methodological basis for ESG-oriented portfolio optimization. It supports the transition from the traditional "return–risk" model to a broader framework that includes financial indicators, ESG criteria and investor preferences. Its application improves transparency, comparability and flexibility in portfolio decision-making.

Based on the review, we can identify several key functions of the ICA in the tasks of ESG-oriented portfolio optimization.

Table 1 – Multi-criteria analysis functions in ESG-oriented portfolio optimization

MCA function	Function Content	Value for the ESG portfolio
Integration	Combining financial and non-financial criteria	Allows you to take into account profitability, risk and ESG indicators in a single analytical model.
Filtration	Exclusion of assets that do not meet specified requirements	Helps to create an investment universe based on ESG constraints
Ranking	Determining the comparative attractiveness of investment alternatives	Allows you to identify companies with the best combination of financial and ESG characteristics.
Weight room	Determining the relative importance of criteria	Reflects the preferences of the investor, the investment committee, or the structure of the source data
A compromise	Finding a balance between conflicting goals	Reduces the contradiction between profitability, risk and sustainability
Explanatory	Increasing the transparency of the investment decision	Allows you to justify the structure of the ESG portfolio and the logic of asset selection.
Note: compiled by the authors based on the generalization of scientific literature on MCDA/ MCDM, ESG investing and portfolio optimization.		

These tables allow us to establish that the MCA performs not one, but several interrelated functions. It can be used as a pre-selection tool, a method for evaluating assets, a mechanism for aggregating criteria, and a way to explain the final portfolio decision. This makes it especially important for ESG investing, where it is required not only to optimize the financial result, but also to show the compliance of the portfolio with the principles of sustainability.

The review also allows us to form a logical model for integrating ESG criteria into a portfolio solution. In a generalized form, it can be represented as follows:

Financial indicators → ESG indicators → normalization → weighting → aggregation → ranking → portfolio optimization.

At the first stage, a set of financial and non-financial indicators is formed. At the second stage, their normalization is carried out, since the indicators have different units of measurement and evaluation scales. At the third stage, the weights of the criteria are determined. At the fourth stage, the integral asset valuation is calculated. At the fifth stage, assets are ranked according to the degree of investment attractiveness. At the sixth stage, the ranking results are used to form or optimize the portfolio. This sequence makes the ESG integration process more systematic, transparent, and reproducible.

An important result is that the MCA can be used in both static and dynamic problem formulation. In the static model, criteria and weights are fixed at the time of making an investment decision. This approach is useful for comparative analysis of assets over a certain period of time. However, in a changing market environment, dynamic formulation is more promising, in which financial and ESG indicators are revised over time (Taheripour et al., 2025). This is especially important for ESG criteria, as companies may improve or worsen sustainability indicators, change disclosure policies, face new regulatory requirements or reputational risks.

The dynamic logic of the ICA allows us to consider ESG integration not as a one-time inclusion of the rating in the model, but as an ongoing process of monitoring investment attractiveness. This approach corresponds to the modern understanding of portfolio management, where the portfolio structure must adapt to changes in both market and non-financial factors.

Of particular importance is the use of ICA to analyze the sustainability of the results. Since the final asset rating depends on the selected criteria, normalization method and weights, it becomes necessary to check the sensitivity of the model. Sensitivity analysis makes it possible to determine whether the asset ranking is maintained when the weights of the ESG criteria are changed, individual indicators are excluded, or an alternative ICA method is used (Goutte et al., 2025; Taheripour et al., 2025). If the results remain stable, we can talk about the high stability of the model. If small changes in the parameters lead to a significant change in the rating, this indicates the need for additional verification.

Sensitivity analysis is especially important for ESG portfolio optimization because ESG data is often less standardized than financial indicators. Therefore, the correct application of the ICA should include not only the calculation of the integral rating, but also the verification of its stability to methodological assumptions.

Another result is that the ICA avoids excessive reduction of the ESG to a single aggregated indicator. In many practical models, the ESG rating is used as a single numeric indicator. However, this approach may conceal the internal structure of the company's sustainability. For example, a company may have a high overall ESG rating due to strong corporate governance, but at the same time demonstrate weak environmental performance. Or, conversely, a company may have a well-developed environmental policy, but insufficiently sustainable social practices.

The ICA allows you to maintain the multidimensionality of the ESG assessment, considering environmental, social and management criteria separately. This is especially important for investors who seek to control not only the overall level of ESG, but also the sustainability structure of the portfolio. In this sense, multi-criteria analysis makes ESG integration more meaningful, as it allows analyzing not only the final score, but also the contribution of each component to the overall assessment.

The use of ICA contributes to the formation of a more balanced methodology for sustainable investment. Unlike approaches based only on the exclusion of companies that do not meet ESG requirements, the ICA allows you to take into account quality gradations and build a more flexible investment strategy. The company may not be perfect in all ESG parameters, but at the same time demonstrate improved performance, high financial stability and an acceptable level of risk. In such a situation, the ICA allows us to evaluate it not binarily, but comprehensively.

This is especially important in emerging markets, where ESG data may be less complete and disclosure levels may be uneven. In such circumstances, rigorous screening can lead to an excessive narrowing of the investment universe. The ICA, on the contrary, allows for a more flexible evaluation system where a company's weaknesses can be compared with its strengths. This approach increases the practical applicability of ESG integration and makes portfolio optimization more adaptive.

Thus, the results of the review analysis show that multicriteria analysis is not an auxiliary, but a system-forming tool for ESG-oriented portfolio optimization. It provides a transition from a simple "return-risk" model to a more complex "return-risk - ESG - investor preferences" model. Its application allows combining financial and non-financial criteria, taking into account individual investment priorities, increasing transparency of decisions, conducting sensitivity analysis and forming more sustainable portfolio strategies.

Discussion. The results show that multi-criteria analysis is an important methodological tool for the development of ESG-oriented portfolio optimization. Its main advantage lies in the ability to combine financial and non-financial criteria into a single investment decision-making system. Unlike the classical model, which

is based primarily on the ratio of profitability and risk, the ICA allows for a broader set of factors to be taken into account, including liquidity, volatility, financial stability, environmental responsibility, social impact, and the quality of corporate governance (Markowitz, 1952; Zopounidis and Doumpos, 2002).

The ICA acquires special importance in conditions of heterogeneity of ESG data. Research shows that ESG ratings of different providers can vary significantly due to differences in assessment methodologies, sets of indicators, and weights of criteria (Berg, Kolbel, Rigobon, 2022). Under these conditions, a multi-criteria analysis allows us not to limit ourselves to using a single aggregated ESG indicator, but to consider environmental, social and managerial parameters as independent elements of an investment assessment.

The practical significance of the ICA is that it makes the portfolio selection process more transparent and understandable. The investor gets the opportunity to see which criteria have been used, how they have been normalized, what weights have been assigned to them, and why individual assets receive a higher or lower valuation. This is especially important for institutional investors, for whom ESG integration is associated not only with financial efficiency, but also with reputational stability, accountability and compliance with the principles of responsible investment (Aouni et al., 2018; Xidonas et al., 2024).

However, the use of ICA has certain limitations. The results of a multi-criteria assessment depend on the choice of criteria, the normalization method, the method of determining weights, and the quality of the initial ESG data. The subjective definition of weights can increase the influence of expert preferences, whereas objective methods do not always reflect the strategic goals of the investor. Therefore, the use of ICA in ESG portfolio optimization should be accompanied by sensitivity analysis and validation of the sustainability of the results (Goutte et al., 2025; Taheripour et al., 2025).

Thus, the ICA should not be considered as a substitute for the classical portfolio theory. It is more correct to consider it as a methodological extension of the traditional approach, which makes it possible to adapt portfolio optimization to modern requirements of sustainable financing. Its application is particularly promising in hybrid models, where multi-criteria evaluation is used in conjunction with multi-purpose optimization, ESG screening and analysis of investment constraints.

Conclusion. The conducted research allowed us to systematize scientific approaches to the application of multicriteria analysis in ESG-oriented portfolio optimization. It is established that the ICA expands the traditional model of portfolio choice “return - risk” and allows you to take into account a wider set of financial and non-financial criteria. This is especially important in the context of the development of sustainable investment, when the investment attractiveness of an asset is determined not only by financial indicators, but also by the environmental, social and managerial characteristics of the company.

The results of the review show that the ICA performs several key functions: integration, filtering, ranking, weighing, compromise and explanatory. It can be

applied at different stages of the investment process.: during the preliminary ESG screening, the construction of ESG scoring, asset ranking, the determination of weights of criteria and the inclusion of ESG parameters in optimization models.

It is concluded that multicriteria analysis is not an alternative to the classical portfolio theory, but its methodological development in the context of sustainable financing. Its application makes it possible to form more balanced investment decisions that combine financial rationality, ESG priorities and investor preferences.

The prospects for further research are related to the empirical verification of the proposed approaches in specific stock markets, the comparison of various ICA methods, the analysis of the sensitivity of ESG portfolios to changes in the weights of criteria, and the development of hybrid models combining MCDA/MCDM, multi-purpose optimization, and risk management tools.

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